1854MNRAS..14..225M

with this interesting subject. At the same time he took occasion to point out the imperfect definition of the inequalities on the bright limb of the moon, and remarked that this was a defect of photographic representations, which placed them in strong contrast with the results of direct observation. To devise adequate means for remedying this defect was one of the principal objects to be aimed at in such experiments, and it was an essential element of success that there should be a contrivance for applying an equable and smooth motion to the surface destined to receive the photographic impression.

Mr. Burr states, in reference to his observation of the occultation of Mars inserted in the last *Monthly Notice*, that the estimated longitude of his observatory is $23^{s}\cdot8$ W.

Account of Observations of the Total Eclipse of the Sun of November 30, 1853, *made at Ocucaje, in Peru.* By M. Carlos Moesta.*

(*Communicated by Admiral W. H. Smyth.*)

The author of this account, who is Director of the National Observatory at Santiago, Chili, was appointed by the Chilian Government to proceed to the neighbouring republic of Peru for the purpose of making observations of the total eclipse of the sun which was to occur on the 30th of November, 1853.

By a graphic delineation, based upon the results given in the *Nautical Almanac*, M. Moesta found that the central line of the totality of the eclipse would enter the coast of Peru from the Pacific at a point situated in long. 76° 2′ west, and lat. 14° 27′ south. Pisco was the nearest town to this part of the coast, but M. Moesta resolved to observe the phenomenon at some convenient place in the interior, elevated as much as possible above the level of the sea.

The various instruments required for observing the phenomenon were obtained from the Observatory of Santiago. Among these was an achromatic refractor of $4\frac{1}{2}$ inches aperture and $5\frac{1}{3}$ feet focal length, by Frauenhofer, furnished with a reticulated micrometer adapted for measuring differences of right ascension and declination, and also angles of position. Another telescope, a refractor, by Dollond, of $2\frac{3}{4}$ in. aperture and $3\frac{1}{2}$ feet focal length, was used by M. Lira, the assistant of the Observatory, who accompanied the author in his expedition. Besides these two instruments, the Observatory furnished for the observation of the phenomenon a reflecting circle by Ertel, divided to every 10″, fitted with two

---

* This Report was originally drawn up by M. Moesta and presented to the Minister of Public Instruction of the Chilian Republic.

1854MNRAS..14..225M

verniers, a sextant by Pistor, a good chronometer by Parkinson and Frodsham, a barometer, and various thermometers.

The author embarked at Valparaiso on the 1st of November, and arrived at Pisco on the 9th of the same month. By means of ten altitudes of the sun, taken on the 11th, he found that this town was situate $22^{m}\ 12^{s}{\cdot}78$ west of the meridian of the Observatory of Santiago. On the 13th of November, while still residing at Pisco, the author carefully examined the sun's disk with the view of ascertaining whether any spots or faculæ were visible which might serve to throw light upon some of the phenomena of the approaching eclipse. Two spots were visible near the eastern margin of the disc, one of which consisted of a group of smaller spots united together like the links of a chain. These spots continued to be seen till the 20th of the month, but no other spot had appeared on the eastern margin of the disc during the interval of their being visible. It is to be remarked, also, that these could not have remained on the disc till the time of the eclipse.

Finding that Pisco was situate in an unfavourable locality for observing the eclipse, the author removed from that town on the 23d, and arrived on the 25th at Ica, which from an old Spanish map he concluded to lie in the central line of the shadow. He found, however, from observations made on the evening of his arrival that the latitude of Ica was in reality only 14° 5′, and that it was situate $1^{m}\ 56^{s}$ to the east of Pisco. It was accordingly necessary to advance about eighteen miles farther towards the south. On the evening of the 27th M. Moesta therefore pursued his journey in that direction, bearing a little towards the east, and on the following morning arrived at Ocucaje, a place which from actual observation he found to be situate in lat. 14° 21′, and to be 20^{s} east of the meridian of Ica. He consequently found himself within about half a mile of the central line of the shadow.

M. Moesta selected for the place of observation an eminence, which, from barometrical measurement, he found to be 880 feet above the level of the sea. On the 28th, he observed a series of corresponding altitudes of *α Eridani* and *α Argus*, from which the latitude appeared to be 14° 21′ 21″. On the morning of the 30th, the sky was everywhere overcast, but about 8 o'clock the sun made his appearance, and the heavens gradually cleared up, promising to afford a full view of the eclipse to the numerous spectators who had congregated to this sequestered spot for the purpose of witnessing so unusual a phenomenon.

All the necessary preparations were now made for observing the eclipse. The error of the chronometer was determined by several altitudes of the sun. The telescopes were placed in appropriate positions. It was arranged that M. Lira should note the variations of the barometer and thermometer; Mr. Clark, an intelligent traveller from North America, undertook to observe all the phenomena which might be visible to the naked eye.

The following account of the appearances observed during the eclipse is thus given by the author:—

1854MNRAS..14..225M

"A few hours before the commencement of the eclipse, I examined the disk of the sun with the Frauenhofer refractor, in order to ascertain whether any spots were visible, and to fix their position if there should be any; but all my efforts were unsuccessful. There was not the slightest spot or interruption of the surface, and the disc appeared perfectly round. I make particular mention of this circumstance on account of its importance as regards the red protuberance seen during the total obscuration, since it has been generally supposed that some relation exists between these phenomena and the solar spots. I shall presently have occasion to speak of this protuberance.

"Two minutes before the commencement of the eclipse, I directed my telescope to the point of the margin of the sun where it was expected that the moon would make her exterior contact. At $2^h\ 13^m\ 25^s{\cdot}5$ mean time of the place of observation, I perceived the first contact of the two discs. No extraneous phenomenon appeared to accompany this occurrence. The moon gradually advanced over the sun's disc; her projection upon the latter tracing out a dark and well-defined arc. On the southern margin of the moon, many elevations were visible, but none of them was sufficiently prominent to admit of ascertaining its height. At $2^h\ 52^m$ the whole western part of the horizon had cleared up. At $3^h\ 8^m$ the small clouds in the vicinity of the sun had disappeared, but the horizon towards the north and east still remained covered with dense clouds. At this time the wind from the south blew with less violence, and the cold began to make itself sensible. The landscape and surrounding objects had changed their colour, and everything seemed to announce the approach of the decisive moment. At $3^h\ 32^m$, while fixing my attention on the eastern part of the sun's disc, where the uncovered space gradually became narrower and narrower, while the two limbs of the sun and moon were perfectly distinguishable, a nebulous substance of a reddish colour, apparently in a state of ebullition, all of a sudden filled up the space between the two limbs. This substance appeared to be traversed by a vein of colour more obscure. It continued to accumulate as the space between the two limbs became narrower, as if it had been forced up between them. Finally, it acquired a ruddy colour of so dark a tinge that it became difficult to distinguish clearly the two limbs. The contact of the latter took place at $3^h\ 32^m\ 15^s{\cdot}5$; at the same instant the last ray of the sun and the last trace of the nebulous substance vanished. From this moment the eclipse presented a very imposing aspect, nature appearing in all her majesty.

"The moon, whose diameter was then 82″ greater than that of the sun, resembled a round and perfectly black circle, and to the naked eye appeared extremely well defined at its circumference. Around it was visible a luminous ring called a *corona of light*, whose soft lustre had a colour between white and azure, like the light of a gas-burner. The light of the ring was as bright, at the part where it touched the moon, as the light of the full moon in a

1854MNRAS..14..225M

clear night at Santiago; but its intensity diminished rapidly, insomuch that, at a distance equal to a fourth part of the lunar diameter, it confounded itself with the pale light of the sky. Conceiving for a moment a vertical circle passing through the centre of the moon, the ring will then divide itself into two parts; viz. one situate to the south, and the other to the north, of the circle in question. Almost all the northern part of the ring was uniform; the opposite part, however, was composed of numerous rays which appeared to issue from the ring, and which all seemed to have the same length with the exception of two very large rays. With respect to the latter, one of them was perceived to shoot upwards, inclining at an angle of 20° to the south of the vertical, and according to estimation extended to a distance equal to the diameter of the moon. The other issued downwards, not diametrically opposite to the former, but inclined about 10° to the north of the vertical, and was rather shorter. The aspect of these two rays very much resembled the tail of a comet, which was narrower at the extremity than at the nucleus, and which was very radiant in all its structure, since they manifestly did not emit a uniform light, but were composed of numerous small rays.

"Immediately after the sun was entirely concealed from view there was visible, in the northern part of the corona of light, a rose-coloured protuberance resembling a cloud, which seemed to issue from the margin of the moon. Its form, which was longitudinal, and also its initial position, are indicated in the sketch.* The colour of this protuberance was not uniform, but was evidently darker in some parts than it was in others. The form continued the same, but as regards its position, I thought I could be certain that it moved towards the ray which shot upwards from the *corona of light*. Gradually its colour became fainter, and after the lapse of about $1^m\ 20^s$ from its first appearance, the whole of the protuberance had vanished. With a position-micrometer I measured its height above the margin of the moon, which I found to be 1′ 8″.

"On the same side of the *corona* there were seen during the whole time of the obscuration two dark spots, not round, but rather of a square form, and attached to the margin of the moon. It seemed as if there had been an interruption of the ring in that part, or rather two apertures through which the dark ground of the heavens was visible. This could be no optical illusion, since many persons were present who could discern the spots referred to perfectly well with the naked eye. Their height above the margin of the moon was estimated at 1′. * * * * *

"The corona disappeared instantaneously with the reappearance of the first ray of the sun, since neither before nor after the total obscuration was the slightest vestige of it to be seen: there was also a similarly sudden change in the brightness of the atmosphere. So long as even the smallest part of the solar disc remained uncovered, it was possible to perceive surrounding objects almost as well as on an

---

* The drawing here referred to has not been communicated to the Society.

1854MNRAS..14..225M

ordinary day, except that every object assumed a peculiarly pale hue. At the moment of the sun being wholly concealed from view, there suddenly came on a kind of darkness very different from that which usually characterises the evening twilight. Towards the horizon, and over the whole north and east where the sky continued cloudy, the darkness of the atmosphere resembled night; while, on the other hand, in the neighbourhood of the moon it was much less intense. The degree of obscurity may be judged of from the following observations:—the planets *Venus* and *Jupiter* were seen in all their brilliancy; *Antares*, which was within 5° of the sun, and was consequently in the immediate vicinity of the corona, was distinctly visible to the naked eye; and as that star is between the first and second magnitude, it might be generally asserted that the degree of obscurity was such as to allow of stars of the second magnitude being seen. There was not sufficient time to look for other stars.

"I had beforehand placed the first page of the *Nautical Almanac* near the telescope, and during the total obscuration I could read it very distinctly at the distance of two or three feet. M. Lira could read the scale of the thermometer without the least difficulty.

"The total obscuration lasted 2^{m} 59^{s}, since it ended at 3^{h} 35^{m} $14^{s}\cdot6$.* *Jupiter* remained visible some minutes afterwards, and *Venus* shone brilliantly till 4^{h} 3^{m}, that is to say, twenty-eight minutes after the total obscuration."

* * * *

The author remarks, that the researches on the physical constitution of the sun seem to indicate the existence of a dark body enveloped in two atmospheres, the interior being non-luminous and somewhat resembling our own atmosphere, while the exterior one, or photosphere, is the exclusive source whence emanates the solar light. Referring, then, to the observations of the total eclipses of the sun of 1842 and 1851, he thus proceeds:—

"All these observations render it probable that the sun has a third atmosphere, imperfectly diaphanous, enveloping the photosphere, and that through the apertures of the spots there issue gaseous exhalations, which, rising to the third atmosphere, form there the coloured clouds, constituting the observed protuberances.

"Thus it arises that our knowledge relative to the physical constitution of the sun depends chiefly upon exact observations of total eclipses of that body, and it is, consequently, of importance that we take advantage of such eclipses as successively occur, in order to improve and amplify the little that we know upon that subject.

"Turning now to the observations made in Peru, I have to remark, that there was visible during the total obscuration a red protuberance, although a corresponding spot on the sun's disc was

---

* The author states in another part of his account that the eclipse terminated at 4^{h} 43^{m} $41^{s}\cdot8$.

1854MNRAS..14..225M

not afterwards perceived. *It hence results that the supposed connexion between the spots visible on the solar disc and the red protuberances is destitute of foundation*, and that the so-called protuberances are in reality gaseous exhalations, which becoming visible in the third atmosphere, must have issued, during the eclipse of the 30th of November, through very small apertures of the photosphere. Such an hypothesis is by no means improbable, since there is always discernible on the solar disc, by the aid of powerful telescopes, a net-work of pores subject to perpetual change.

"The short duration of the protuberance, joined to its change of colour and its apparent motion, are circumstances which seem to indicate the imperfect transparency of the third atmosphere, as well as whirling currents of wind which occur in it, analogous to those which prevail in the terrestrial atmosphere.

"The corona of light has been seen during several former eclipses, but, as far as I am aware, in no instance with such brilliancy, or with such a peculiar form, as on the present occasion. The radiant light of the corona, throughout all its southern side, strongly resembled the aurora borealis; but the two large emanations of light, above referred to, exhibiting the radiation upon a much larger scale. The contrast between this part of the corona and the northern part, whence a soft light, unaccompanied by rays, appeared to emanate, imparted a singular aspect to the phenomenon. I am of opinion, that the latter may be satisfactorily explained by supposing the activity of the photosphere, not to be equal in all its parts, but that by some cause it is more violently agitated in certain places than in others. It is not so easy to give a satisfactory explanation of the two dark spots above mentioned. I refrain from making any remarks upon the extreme transparency of the terrestrial atmosphere in this part of Peru. The foregoing observations sufficiently attest this fact."

Meteorological and other Observations made during the Eclipse.

In order to ascertain with greater precision the influence of the eclipse upon the thermometer, M. Moesta caused observations with two thermometers to be made, not only on the day of the eclipse, but also on the preceding and following days. One of these thermometers was placed in the shade; the other, which had a blackened bulb, was exposed to the direct influence of the sun's rays. The author then gives the details of the observations on each day. It appears from them, that on the 30th of November, during the time comprised between the commencement of the eclipse and the total obscuration, the thermometer exposed to the sun, sank $22^{\circ}\cdot5$ Fahrenheit, after which it continued to rise till $4^{h}\ 15^{m}$, attaining, in this interval, an elevation of $3^{\circ}\cdot8$. On the other hand, the same thermometer was observed on the 29th to descend $5^{\circ}\cdot2$ during

1854MNRAS..14..225M

the former of these two intervals, and *continued to descend* 6°·7 during the latter interval. On the 1st of December the descent, during the former interval, was 9°·7.

"A change of 14°·4 in the temperature during little more than an hour ought certainly," says the author, "to make itself sensible; and the truth is, that during the time of the total obscuration I was shivering with cold." This sudden fall of the temperature was accompanied by an interesting phenomenon, which manifested itself under very striking circumstances. At the entrance of the shadow on the coast of Peru, the air, usually so hot from the sandy plain upon which it rests, suddenly condensed from the effect of the eclipse, and this caused a current of cool air to flow from the ocean for the purpose of restoring the equilibrium of the atmosphere. There ought from this cause to have been a wind from the west; however, as a cool breeze from the south had continued to blow during the whole day, there was a violent meeting together of two distinct currents, and the consequence was, that during the total obscuration a succession of whirlwinds occurred which in some instances raised the sand to a height of 200 feet.

Another phenomenon strongly attracted the attention of the author,—a species of cloud of a pale azure colour, mingled with purple. To the south of his position, at the distance of half a league, a table-mountain was situate, from which this cloud appeared to ascend in columns at three o'clock in the afternoon. It continued to augment till the time of the total obscuration, when it presented a very dense and black aspect. It then gradually grew less, and, finally, disappeared a little before the termination of the eclipse.

M. Moesta also remarked that, during the total obscuration, the leaves of the carob-tree closed up as if it were night, and resumed their natural position shortly after the reappearance of the sun. In the case of the leaves of the cotton-tree, Mr. Clark noticed a similar change. The latter also remarked that, during the total obscuration, all sorts of insects disappeared, that the fowls grouped together, and that other species of poultry continued flying about very near the ground. "Great," says the author, "was the impression which the occurrence of so many rare phenomena during the total obscuration produced on the minds of the spectators, who all saluted with enthusiasm the first rays of the sun on the occasion of his reappearance."